IRRIGATION AND NITROGEN MANAGEMENT WITH A SITE-SPECIFIC CENTER PIVOT

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ABSTRACT

In 1999-2000, the effects of water and N-fertilizer rates on maize grain yield were determined using two center pivot irrigation systems modified to provide site-specific water and fertilizer applications to management zones as small as $100m^2$. One system (CP1) was sited on a fairly uniform soil. The other (CP2) included 12 soil map units. At both, maize grain yield increased with increased irrigation amount. Yield increased with N-fertilizer rate on CP1, but yields were not different for the two N-fertilizer rates on CP2. Yield responses to total water varied among the soil map units. Irrigation increased a rainfed yield from 2 to 11 Mg/ha on one soil, but only increased yield on another from 4 to 7 Mg/ha. This information will allow managers to allocate water and fertilizer resources to soils where it will be most beneficial.

INTRODUCTION

Improved positioning systems and yield monitors have allowed identification of yield patterns that may be related to site conditions and management inputs. Water and fertilizer are two management inputs that directly affect crop yield and both are amenable to site-specific management. Site-specific application of fertilizers over large areas using ground-driven equipment has been practiced in the USA for several years but most irrigation is still being applied uniformly within a system. Some commercial traveling irrigation systems with programmable management systems allow variable application depths in the direction of travel by changing system speed. More precise, dynamic control of water and fertilizer applications requires smaller management zones both in the travel direction and along the system structure.

When commercial systems that permit dynamic control of water and nutrients to small management zones become available, crop yield functions will be needed to optimize resource allocation. These functions will be required for a range of water and nutrient inputs on all soils within the managed area. Generalized fertilizer recommendations may be useful but more specific responses for individual soils will be needed to optimize economic return and minimize environmental damage. Little information has been published on maize response to irrigation and fertilizer rates for diverse soils. Lamm et al. (1993) found that management-induced variations in crop production had major impact on maize yield and profit in a study with nine combinations of irrigation, fertilizer, and seeding rate. Others have investigated the impact of various irrigation and fertilizer inputs on maize yield in the USA but mostly on a single soil map unit (Ferguson et al., 1991; Gascho and Hook, 1991; Oberle and Keeny, 1990; Sexton et al., 1996).

The objective of this experiment was to determine maize grain yield response to a range of irrigation levels and N-fertilizer rates at two sites in the southeastern Coastal Plain of the USA; one with uniform soils and one with extremely variable soils.

MATERIALS AND METHODS

In 1999 and 2000, experiments to determine the effect on maize grain yield for a range of irrigation and N-fertilizer amounts were conducted in Florence, South Carolina, USA, on two commercial, three-span center pivot irrigation systems that had been modified to provide site-specific water and fertilizer applications. Each center pivot was 137 m long and had an irrigated area of 5.8 ha. The variable-rate water application system on both center pivots consisted of 13 segments along the truss length, each 9.1 m long, ending on the outer tower. With the center pivot operating at 50% speed, each segment could independently apply 0 to 12.7 mm in seven equal steps. The variable-rate application system on each center pivot was controlled by a computer, which was connected to a programmable logic controller (PLC). Using angular position data obtained from the center pivot controller, spatially-indexed data stored on the computer, and software developed by USDA-ARS in Florence, the PLC switched the proper valves to obtain the appropriate application depth for each management zone. Nitrogen fertilizer was applied by injecting urea ammonium nitrate (UAN) into the center pivot water line via a variable-speed pump at rates that maintained a constant concentration in the water distribution system. Variable N amounts were applied to each management zone by varying the water amount. Additional details regarding the site-specific center pivot irrigation systems were reported by Sadler et al. (1997) and Camp et al. (1998).

The first center pivot system (CP1) included two similar soils (Norfolk lfs (NkA) and a deeper Norfolk lfs (NoA)). Treatment variables included three irrigation regimes (0, 75%, and 150% of a base rate) and four N-fertilizer regimes (50%, 75%, 100%, and 125% of a base rate). The irrigation base rate was intended to provide adequate water for crop growth and development. There were two N-fertilizer base rates, one for rainfed (135 kg/ha) and another for irrigated treatments (225 kg/ha), as recommended by the South Carolina Cooperative Extension Service. Four replications of each treatment resulted in 144 plots in a randomized complete block design. Each plot was 9.1 m (12 rows) wide and 10 to 16 m long.

The second center pivot (CP2) was sited on a typical, highly-variable Coastal Plain field that included 12 very diverse soil map units. These soils were Bonneau lfs (BnA), Coxville l (Cx), Dunbar lfs (Dn), Dunbar lfs overwash (Do), Emporia fsl (ErA), Goldsboro lfs (GoA), a deep Noboco lfs (NcA), Noboco lfs (NbA), Noboco fsl (NfA), Norfolk lfs (NkA), a deep Norfolk lfs (NoA), and Norfolk fsl (NrA). Soil map units were determined by USDA-NRCS personnel from samples taken on a 15-m by 15-m grid, with additional sampling to identify soil boundaries and mapped on 1:1200 scale. Additional information on the site and cropping history were reported by Karlen et al. (1990) and Sadler et al. (1995). At the CP2 site, irrigation treatments included 0, 50, 100, and 150% of a base irrigation rate. N-fertilizer rates were the recommended rainfed and irrigated rates (135 and 225 kg/ha). The number of treatment combinations and number of replications within a soil map unit varied, depending upon the available land area within a specific soil map unit. This design provided a total of 396 plots (39 complete blocks and 18 incomplete blocks), with each plot about 9 m by 9 m in size (Millen et al., 2000).

Conservation tillage culture was used on CP1 and conventional surface tillage (disking) culture was used on CP2, and both were subsoiled to a depth of 40 cm within the row at planting. In CP1, glyphosate (Roundup[7]) was applied broadcast prior to planting to control weeds. Granular fertilizer was applied broadcast to both sites prior to planting (31 kgN/ha, 23 kgP/ha, and 44 kgK/ha to both CP1 and CP2 in 1999; 45 kgN/ha, 30 kgP/ha, and 121 kgK/ha to CP1 in 2000; and 45 kgN/ha, 43 kgP/ha, and 139 kgK/ha to CP2 in 2000). Maize (c.v. Pioneer 3163*) was planted 22-23 March 1999 and 30-31 March 2000, using a six-row planter at a seeding rate of 71,500 seeds/ha. Final plant population was about 64,000 plants/ha. Pre-plant, pre-emergence, and post-emergence herbicides and a banded insecticide were applied as recommended by South Carolina Cooperative Extension Service. Urea ammonium nitrate with sulfur (UAN 24S) was applied according to the treatment plan via the irrigation systems at both sites during the period 28 May - 3 June 1999 and 19 - 25 May 2000. Soil water potential (SWP) was measured using tensiometers at two depths (30 and 60 cm) and multiple locations at each experimental site. Measurements were recorded three times each week and data were used to determine irrigation initiation and to monitor SWP. Irrigation was initiated in all irrigation treatments when mean SWP at the 30-cm depth was $\geq$30kPa. The irrigation base rate for both sites varied during the growing season (4-13 mm/application) depending upon crop growth stage and weather conditions. A 6.1-m length of two rows near the center of each plot was harvested during the period 31 Aug. - 13 Sept. 1999 and 13 Sept. - 2 Oct. 2000 using a plot combine. Maize grain yields were determined by weighing the harvested grain and correcting to 15.5% moisture. Yield data were statistically analyzed using regression analysis (Statistical Analysis System, SAS Institute, Cary, NC.).

RESULTS AND DISCUSSION

Growing season total irrigation and rainfall amounts are shown in Table 1 for all treatments in both CP1 and CP2 for 1999 and 2000. Irrigation amounts were less for all treatments in 2000 than in 1999, which is consistent with the greater rainfall amount that year. Based on the irrigation amounts required for the 150% rate (only rate common to both CP1 and CP2), CP1 required more irrigation than CP2 in 1999 but both required equal amounts in 2000. Total water amount (rainfall and irrigation) ranged from 286 mm (rainfed, no irrigation in 1999) to 715 mm (150% rate in CP1 in 1999). However, some of the rainfall during thunderstorms was probably lost to runoff and not available for crop use.

TABLE 1. Seasonal rainfall and irrigation amounts for CP1 and CP2 during the 1999-2000 in Florence, SC.

Year	Irrigation depths for various treatments					Rainfall
	CP1		CP2			
	75%	150%	50%	100%	150%	
	------------------------- mm --------------------------					
1999	214	429	109	218	325	286
2000	144	288	96	192	288	375

On CP1, where the soils were fairly uniform (mostly NkA), mean maize grain yields increased with irrigation rate both years, ranging from 6.4 to 10.1 Mg/ha (Figure 1). Maize yields also increased with amount of N fertilizer applied, but absolute yield increases were less for the rainfed treatments than for the irrigated treatments (Figure 2). Mean maize grain yields ranged from 5.4 to 7.3 Mg/ha for the rainfed treatments and from 8.1 to 10.9 Mg/ha for the irrigated treatments. In both cases, the yield response curves for individual years cross near the 75% recommended rates (101 and 169 kg/ha for rainfed and irrigated, respectively).

* Mention of a trade name, proprietary product, or specific equipment does not constitute a guarantee or warranty by the USDA and does not imply approval of a product to the exclusion of others that may be suitable.

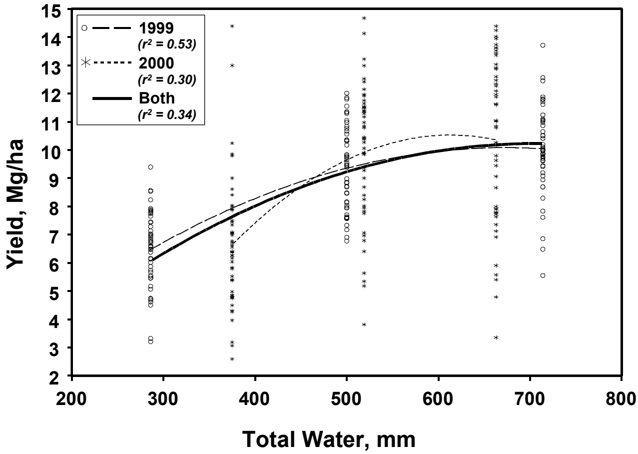

FIGURE 1. Maize yields across N-fertilizer treatments for various total water treatments in CP1 during 1999-2000 at Florence, SC.

For the NkA soil in CP2, maize grain yields increased with total water both years (Figure 3). This soil is in the Norfolk series, has a moderately thick Ap horizon, and occupies about 40% of the area in CP2. Although the yield increase for this soil was greater in 2000 than in 1999 for the range of total water, yields at the greater total water amounts were similar for both years. The yield response curve for both years combined appears to be a reasonable representation of these data, indicating a maize yield range from about 5.8 Mg/ha to about 10 Mg/ha for the 377-mm range in total water. The yield response curve (both years combined) for the NkA soil in CP2 is similar to that for three other soils in CP2 (NcA, NoA, NrA) but somewhat different from that for two other soils (NbA and NfA) (Figure 4). These soils differ in soil series (Norfolk or Noboco) and thickness and texture of the Ap horizon. The NbA soil (Noboco series with moderately-thick Ap) had a greater maize yield increase for the range of total water while the NfA soil (Noboco series with a finer textured Ap horizon) had little yield increase. Except for the NfA soil, which was not particularly responsive to irrigation, r^2 values for the quadratic curves through the means were no lower than 0.62 for these soils. There was no difference in maize yield either year for the two N-fertilizer rates in CP2, which is not surprising based on the results for CP1. The N-fertilizer rates in CP2 were similar to the higher rates used in CP1, which is on the flatter part of the yield response curve. Consequently, the N-fertilizer results for CP2 do not conflict with those for CP1.

Based on these results for 1999 and 2000, the maize yield increased with total water for plant growth, as expected. However, the yield response functions are quite different for some soils. For example, irrigation increased maize yields 7-9 Mg/ha for the NbA, NoA, and NkA soils while there was little increase for the NfA soil. Likewise, maize yields increased with N-fertilizer amount. It appears that the currently recommended rates are generally adequate. This study will be continued for an additional year, which should provide an adequate database for optimizing inputs for site-specific management of maize for areas with similar soils. It is clear that when optimization routines are developed for various soils, water resources should be allocated to those soils that will provide a profitable yield response.

In conclusion, basic information is now available to make specific irrigation and fertilizer application recommendations for individual soils. Using such recommendations, irrigation managers will be able to allocate their resources (both water and fertilizer) in areas where it will be most beneficial.

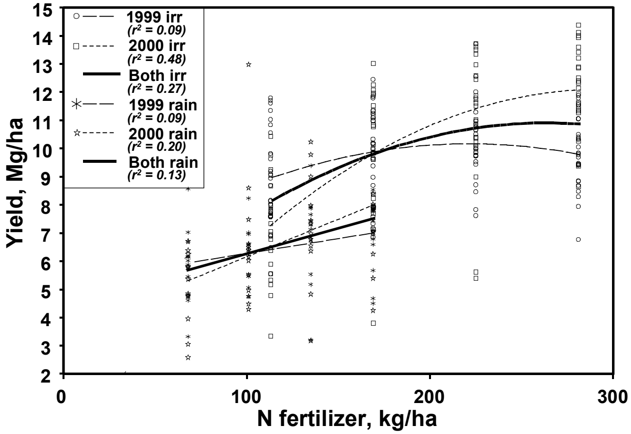

FIGURE 2. Maize yields for various N fertilizer treatments on both rainfed (linear) and irrigated (quadratic) treatments in CP1 during 1999-2000 in Florence, SC.

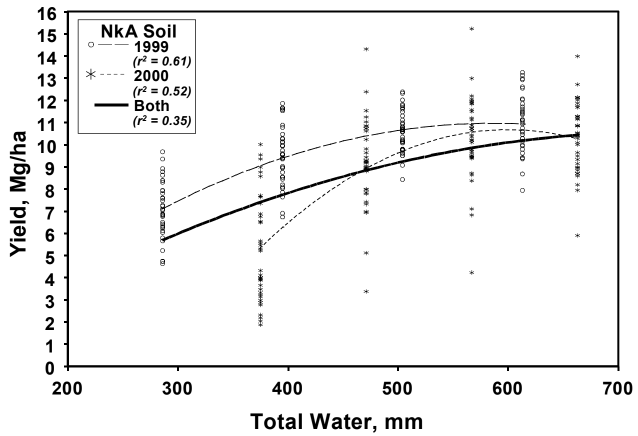

FIGURE 3. Maize yields across two N-fertilizer treatments for various total water treatments on a NkA soil in CP2 during 1999-2000 at Florence, SC.

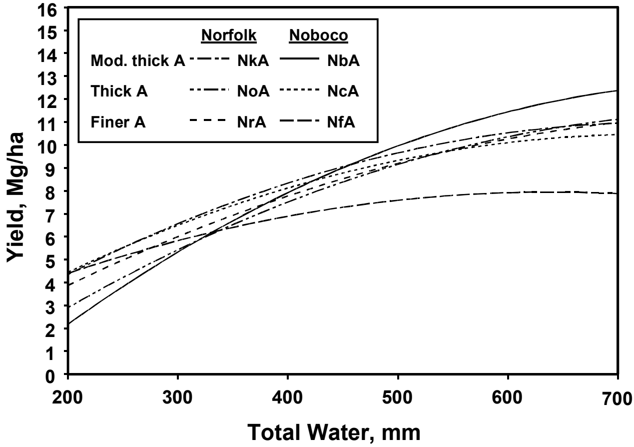

FIGURE 4. Maize yields across two N-fertilizer treatments for various total water treatments and several soils in CP2 during 1999-2000 at Florence, SC.

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